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(71) Applicant: **Denso Corporation**
Kariya-city, Aichi-pref., 448-0029 (JP)

(72) Inventor: **Tetsuya, Watanabe**
Kariya-shi, Aichi-pref. 448-0029 (JP)

(74) Representative:
Pellmann, Hans-Bernd, Dipl.-Ing. et al
Patentanwaltsbüro
Tiedtke-Bühling-Kinne & Partner
Bavariaring 4
80336 München (DE)

(54) Glow plug

(57) An improved sealing structure of a glow plug for diesel engines is provided. The glow plug includes a heater assembly which consists of a heater casing, a heating element, and a power supply rod. The heater casing has disposed therein the heating element connecting with the power supply rod and also has formed on a periphery thereof a press fit wall press-fitted into a hollow housing in tight engagement with an inner peripheral wall of the hollow housing. An uneven surface is formed on one of the press fit wall of the heater casing and the inner peripheral wall of the hollow housing. The uneven surface is patterned with lines such as fine grooves or ridges oriented at an angle relative to a longitudinal center line of the glow plug for forming barriers when the press fit wall is forced into the hollow housing which establish airtight seals between the heater casing and the hollow housing.

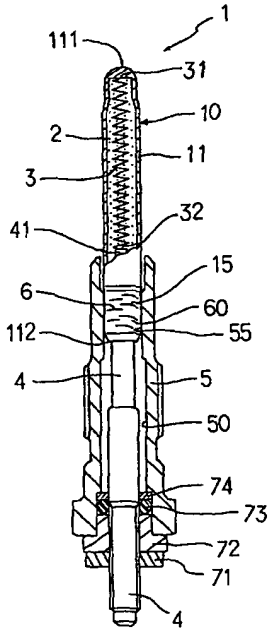

FIG. 2

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Descripti n

FIELD OF THE INVENTION

[0001] The present invention relates generally to a glow plug designed to preheat a combustion chamber of a diesel engine for ensuring quick starting, and more particularly to an improved structure of a glow plug designed to provide for a desired hermetic seal between a heater and a housing in easy assembling.

BACKGROUND ART

[0002] Fig. 1 shows a conventional sheathed glow plug used as a preheating element for diesel engines.

[0003] The glow plug 9 includes generally a heater 90, a central rod 4, and a housing 5. The heater 90 includes a metallic tube 91 which is filled with an insulating powder 2 and which has disposed therein a heating coil 3. The central rod 4 is disposed within the housing 5 and partially inserted into the insulating powder 2. The heating coil 3 is joined at an end 31 to an inner wall of a closed head of the tube 91 and at an end 32 to a head of the central rod 4.

[0004] The heater 90 is retained by the housing 5 in tight engagement of a press fit wall 95 of the tube 91 with an inner wall 55 of the housing 5. The central rod 4 is installed within the housing 5 through a nut 71, resinous bush 72, an insulating O-ring 73, and a resinous washer 74.

[0005] The production of the glow plug 9 involves insertion of the heating coil 3 and the central rod 4 into the metallic tube 91, packing the insulating powder 2 into the metallic tube 91, swaging the metallic tube 91 to hold the central rod 4 tightly, and press-fitting the heater 90 into the housing 5.

[0006] The structure and production of the glow plug 9, however, has the following drawbacks.

[0007] The press-fitting of the heater 90 into the housing 5 must be so achieved as to ensure airtight engagement therebetween enough to withstand a high pressure of about 150 atmospheres acting on the glow plug 9 during use. This requires high roundness and fine surface roughness (i.e., a mirror-finished surface) of the press fit wall 95 of the heater 90, which generally requires use of an expensive and high-performance swaging machine.

[0008] As an alternative to the above press-fitting, Japanese Patent Second Publication No. 59-52726 teaches the airtight engagement of a heater with a housing achieved by inserting the heater with a groove into the housing and staking a portion of a peripheral wall of the housing in the groove of the heater. This, however, has the disadvantages of requiring an additional process of the staking.

SUMMARY OF THE INVENTION

[0009] It is therefore a principal object of the present invention to avoid the disadvantages of the prior art.

[0010] It is another obj ct of the present invention to provide an improved structure of a glow plug designed to provide for a hermetic seal between a heater and a housing in easy assembling.

[0011] It is a further object of the invention to provide a production method of a glow plug which facilitates ease of a press-fitting operation to force a heater into a housing;

[0012] According to one aspect of the present invention, there is provided a glow plug which comprises: (a) a hollow housing having a given length; (b) a heater assembly including a heater casing, a heating element, and a power supply rod, the heater casing having disposed therein the heating element connecting with the power supply rod and also having formed on a periphery thereof a press fit wall press-fitted into the hollow housing in tight engagement with an inner peripheral wall of the hollow housing; and (c) an uneven surface formed on one of the press fit wall of the heater casing and the inner peripheral wall of the hollow housing, the uneven surface having formed thereon a pattern which has a length oriented at an angle relative to a longitudinal center line of the glow plug.

[0013] In the preferred mode of the invention, the uneven surface has a surface roughness of 25 μm or less (Rz).

[0014] The uneven surface occupies 20% or more of an area of one of the press fit wall of the heater casing and the inner peripheral wall of the hollow housing.

[0015] The uneven surface is patterned with lines which are oriented at 30° or more relative to the longitudinal center line of the glow plug.

[0016] The lines of the uneven surface are formed with one of fine grooves and protrusions.

[0017] The press fit wall of the heater casing has a hardness different from that of the inner peripheral wall of the hollow housing.

[0018] An insulating powder is disposed within the heater casing to insulate the heating element from the heater casing. The heating casing has a given length and has formed therein an open end. The power supply rod is partially inserted into the insulating powder through the open end of the heating casing. A sealing member is disposed within the heater casing. The sealing member is made of a sealing liquid which is penetrated into a portion of the insulating powder exposed to the open end of the heater casing and which is hardened to form an airtight seal in the open end of the heater casing.

[0019] The thickness of the sealing member is smaller than the length of a portion of the power supply rod embedded into the insulating powder.

[0020] The sealing member has a permeability of 10^{-5} cc/sec · kg/cm^2 or less and made of a silicone rubber.

The thickness of the sealing member is 0.5 mm or more.

[0021] According to the second aspect of the invention, there is provided a glow plug production method which comprises the steps of: (a) preparing a hollow housing having a given length; (b) preparing a heater assembly including a heater casing and a heating element disposed within the heater casing, the heater casing having a press fit wall formed on a periphery thereof; (c) machining one of the press fit wall of the heater casing and the inner peripheral wall of the hollow housing so as to form an uneven surface with a pattern which has a length oriented at an angle relative to a longitudinal center line of the hollow housing; and (d) forcing the heater casing of the heater assembly into the hollow housing to establish tight engagement between the press fit wall of the heater casing and the inner peripheral wall of the hollow housing.

[0022] In the preferred mode of the invention, the machining step patterns the uneven surface with lines formed with one of fine grooves or protrusions.

[0023] A machining step is further provided which, before forcing the heater casing into the hollow housing, machines an end portion of the heater casing which is to be inserted into the hollow housing to form a guide stem having a diameter smaller than that of the inner peripheral wall of the hollow housing and a tapered wall connecting the press fit wall and the guide stem.

[0024] The guide stem has a length of 3 mm or more.

[0025] A forming step may further be provided which forms a tapered inner wall in the hollow cylinder oriented at an angle relative to the longitudinal center line of the hollow cylinder which is greater than an angle at which the tapered wall of the heater casing is oriented relative to a longitudinal center line of the heater casing.

[0026] The forcing step includes a grasping step of grasping a periphery of the heater casing using a collet and a pressing step of pressing the collect to force the heater casing of the heater assembly into the hollow housing.

[0027] The forcing step further includes a mounting step of, before the pressing step, mounting the heater casing in the hollow housing in alignment.

[0028] The forcing step further includes a second pressing step of pressing a head of the heater casing using a press member after a load applied to the heater casing from the collet reaches a given level.

[0029] The forcing step may alternatively include a grasping step of grasping axially spaced peripheral portions of the heater casing using a first and a second collet and a pressing step of pressing the first and second collets under different pressures, respectively, to force the heater casing of the heater assembly into the hollow housing.

[0030] According to the third aspect of the invention, there is provided a glow plug production method which comprises the steps of: (a) preparing a hollow housing having a given length; (b) preparing a heater assembly including a heater casing and a heating element disposed within the heater casing, the heater casing having a press fit wall formed on a periphery thereof; (c) machining an end portion of the heater casing to form a guide stem having a diameter smaller than that of an inner peripheral wall of the hollow housing and a tapered wall connecting the press fit wall and the guide stem; and (e) forcing the end portion of the heater casing into the hollow housing to establish tight engagement between the press fit wall of the heater casing and the inner peripheral wall of the hollow housing.

[0031] In the preferred mode of the invention, a forming step is further provided which forms a tapered inner wall in the hollow cylinder oriented at an angle relative to the longitudinal center line of the hollow cylinder which is greater than an angle at which the tapered wall of the heater casing is oriented relative to a longitudinal center line of the heater casing.

[0032] According to the fourth aspect of the invention, there is provided a glow plug production method comprising the steps of: (a) preparing a hollow housing having a given length; (b) preparing a heater assembly including a heater casing, a heating element, and a power supply rod, the heater casing having disposed therein the heating element connecting with the power supply rod and also having formed on a periphery thereof a press fit wall; (c) grasping a periphery of the heater casing with arc-shaped surfaces of jaws of a collet; and (d) pressing the collect to force the heater casing of the heater assembly into the hollow housing to establish tight engagement between the press fit wall of the heater casing and an inner peripheral wall of the hollow housing.

[0033] In the preferred mode of the invention, a second pressing step is further provided which presses a head of the heater casing using a press member after a load applied to the heater casing from the collet reaches a given level.

[0034] The grasping step grasps axially spaced peripheral portions of the heater casing using a first and a second collet. The pressing step presses the first and second collets under different pressures, respectively, to force the heater casing of the heater assembly into the hollow housing.

[0035] According to the fifth aspect of the invention, there is provided a glow plug which comprises: (a) a hollow housing having a given length; (b) a heater assembly including a heater casing, a heating element, and a power supply rod, the heater tube having disposed therein the heating element connecting with the power supply rod partially inserted into the heater tube through an open end and also having formed on a periphery thereof a press fit wall press-fitted into the hollow housing in tight engagement with an inner peripheral wall of the hollow housing; (c) an insulating powder disposed within the heater tube to insulate the heating element from the heater tube; and (d) a sealing member made of a sealing liquid which is penetrated into a portion of the insulating powder exposed to the open end of the

heater tube and which is hardened to form an airtight seal in the open end of the heater casing.

[0036] In the preferred mode of the invention, the sealing member has a permeability of 10^{-5}cc/sec • kg/cm^2 or less.

[0037] According to the sixth aspect of the invention, there is provided a glow plug production method which comprises the steps of: (a) preparing a hollow housing having a given length; (b) preparing a heater assembly including a metallic heater tube, a heating element, a power supply rod, and an insulating powder, the heater tube having disposed therein the heating element connecting with the power supply rod partially inserted into the heater tube through an open end and also having formed on a periphery thereof a press fit wall, the insulating powder being disposed within the heater tube to insulate the heating element from the heater tube; (c) penetrating a sealing liquid into a portion of the insulating powder exposed to the open end of the heater tube and hardening the sealing liquid to form an airtight seal in the open end of the heater casing; (d) swaging the heater tube to decrease a diameter thereof; and (e) forcing the heater tube into the hollow housing to establish tight engagement between the press fit wall of the heater tube and the inner peripheral wall of the hollow housing.

BRIEF DESCRIPTION OF THE DRAWINGS

[0038] The present invention will be understood more fully from the detailed description given hereinbelow and from the accompanying drawings of the preferred embodiment of the invention, which, however, should not be taken to limit the invention to the specific embodiment but are for explanation and understanding only.

[0039] In the drawings:

Fig. 1 is a partial cross sectional view which shows a conventional glow plug for diesel engines;
Fig. 2 is a partial cross sectional view which shows a glow plug according to the first embodiment of the invention;
Fig. 3 is a partial plan view which shows a metallic tube of a heater;
Fig. 4 is a partial cross sectional view which shows a press-fit process to force a heater into a housing;
Fig. 5 is a partial plan view which shows the first modification of a heater;
Fig. 6 is a partial plan view which shows the second modification of a heater;
Fig. 7 is a partial cross sectional view which shows the second embodiment of a glow plug;
Fig. 8 is a partial cross sectional view which shows the first modification of the second embodiment;
Fig. 9 is a partial cross sectional view which shows the second modification of the second embodiment;
Fig. 10 is a partial cross sectional view which shows a glow plug according to the third embodiment of the invention;
Fig. 11 is a plan view which shows a portion of a heater to be machined to form a press fit wall and a guide stem;
Fig. 12 is a cross sectional view which shows a housing placed on a holder in a press fit operation;
Fig. 13 is a partial cross sectional view which shows tapered walls of a heater and a housing;
Fig. 14 is a partial cross sectional view which shows a heater inserted into a housing in alignment in an initial stage of a press fit operation;
Fig. 15 is a partial cross sectional view which shows a heater forced into a housing by a press jig;
Fig. 16 is a plan view which shows a modification of a metallic tube of a heater;
Fig. 17 is a partial cross sectional view which shows the first modification of a press fit operation in the third embodiment;
Fig. 18 is a plan view which shows a collet for grasping a heater in a press fit operation;
Fig. 19 is a cross sectional view which shows the collet of Fig. 18;
Fig. 20 is a bottom view which shows a heater grasped by the collet of Fig. 18;
Fig. 21 is a bottom view which shows a modified form of the collect of Fig. 18;
Fig. 22 is a cross sectional view which shows the second modification of a press-fitting operation in the third embodiment;
Fig. 23 is a graph which shows the relation between loads provided by press jigs and a total load applied to the heater;
Fig. 24 is a cross sectional view which shows the third modification of a press-fitting operation in the third embodiment;
Fig. 25 is a graph which shows the relation between loads provided by collets and a total load applied to the heater;
Fig. 26 is a cross sectional view which shows the fourth modification of a press-fitting operation in the third embodiment;
Fig. 27 is a partial cross sectional view which shows the fourth embodiment of a glow plug;
Figs. 28(a), 28(b), and 28(c) show process of penetrating a sealing liquid into an insulating powder packed in a metallic tube of a heater to form a airtight seal;
Fig. 29 is a partial cross sectional view which shows the inside of a metallic tube of a heater after being swaged;
Fig. 30 is a partial cross sectional view which shows a sealing layer forced out of a metallic tube after being swaged;
Fig. 31 is a graph which represents the permeability of a sealing member measured for different values of thickness thereof; and
Fig. 32 is a graph which repres nts the relation between depth of a portion of an insulating powder

into which a sealing liquid penetrates and viscosity of the sealing liquid.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0040] Referring now to the drawings, wherein like reference numbers refer to like parts throughout several views, particularly to Fig. 2, there is shown a glow plug 1 according to the first embodiment of the present invention.

[0041] The glow plug 1 includes generally a housing 5 having formed therein a cylindrical bore 50, a heater 10 press-fitted into the bore 50, and a central rod 4 connecting at an end with a power supply (not shown).

[0042] The attachment of the heater 10 to the housing 5 is achieved by bringing a press fit wall 15 formed on an end portion of the heater 10 into tight engagement with a small-diameter inner wall 55 of the cylindrical bore 50. The press fit wall 15 has an uneven surface 60 on which fine grooves or scratches 6 are formed. Each of the scratches 6 has a length oriented at an angle of 30° or more relative to the longitudinal center line of the glow plug 1 (i.e., the heater 10). It is advisable that the surface roughness (Rz) of the uneven surface 60 be 25 μm or more for ensuring airtight sealing between the heater 10 and the housing 5.

[0043] The heater 10 includes a metallic tube 11 having a closed head 111 and a heating coil 3 disposed within the tube 11. The tube 11 is filled with an insulating powder 2.

[0044] The central rod 4 has a head 41 inserted through an open end 112 of the tube 11 into the insulating powder 2. The heating coil 3 is welded at an end 31 to an inner wall of the head 111 of the tube 11 and at an end 32 to the tip of the central rod 4. Other arrangements are identical with those shown in Fig. 1, and explanation thereof in detail will be omitted here.

[0045] In assembly of the glow plug 1, the metallic tube 11 and the central rod 4 to which the end 32 of the heating coil 3 is attached are first prepared. Next, the heating coil 3 is inserted into the metallic tube 11 and welded at the end 31 to the inner wall of the head 111 of the metallic tube 11.

[0046] The insulating powder 2 made of magnesia (MgO) is packed into the metallic tube 11 to insulate the heating coil 3 and the head 41 of the central rod 4 from the inner wall of the metallic tube 11.

[0047] The metallic tube 11 is swaged to decrease the diameter thereof, thereby increasing the density of the insulating powder 2 in the metallic tube 11 to join the central rod 4 and the heater 10 together.

[0048] The base portion of the metallic tube 11 is ground to form the press fit wall 15 which has a preselected roundness and which has formed thereon the uneven surface 60 patterned with lines (i.e., the scratches 6) as shown in Fig. 3. The adjustment of the roundness and formation of the line pattern are achieved by controlling the feed of a grinding wheel. The uneven surface 60 occupies 20% or more, preferably 90% or more (100% in this embodiment) of a peripheral area of the press fit wall 15 and has formed thereon the scratches 6 uniformly. The scratches 6 may be formed with feed lines extending substantially perpendicular to the longitudinal center line of the metallic tube 11.

[0049] Next, the housing 5 is prepared. The heater 10 is, as shown in Fig. 4, forced into the housing 5.

[0050] The housing 5 has, as described above, formed therein the cylindrical bore 50 which extends longitudinally and which has a heater insertion opening 51. In the cylindrical bore 50, the small-diameter inner wall 55 is formed. The housing 5 is made from material having the hardness smaller than that of the heater 10.

[0051] Next, the housing 5 is, as clearly shown in Fig. 4, placed on a holder 86 with the heater insertion opening 51 facing upward. The heater 10 retained at the head by a press block 81 is inserted into the housing 5 and then pressed by the press block 81 downward to bring the press fit wall 15 into tight engagement with the small-diameter inner wall 55 of the housing 5. This causes the part of material of the small-diameter inner wall 55 contact with the press fit wall 15 to undergo plastic deformation so that it enters the scratches 6 in the press fit wall 15 to form barriers establishing airtight engagement between the metallic tube 11 and the housing 5.

[0052] It is advisable that the press fit wall 15 of the heater 10 be applied with lubricating oil such as fluoro grease, silicone grease, synthetic hydrocarbon-based grease, polyglycol-based grease, or phenylether-based grease in advance for reducing the friction between the press fit wall 15 and the small-diameter inner wall 55 during insertion of the heater 10 into the housing 5.

[0053] Finally, a nut 71, a resinous bush 72, an O-ring 73 made from insulating material, and a resinous washer 74 are installed in and on the end of the housing 5 to hold the central rod 4 hermetically within the housing 5.

[0054] Fig. 5 shows the first modification of the heater 10 which has an uneven surface 62 formed on the press fit wall 15 of the metallic tube 11. The whole of the uneven surface 62 is patterned with a spiral line 6 using a cutting tool. Other arrangements are identical with those in the first embodiment.

[0055] Fig. 6 shows the second modification of the heater 10 which has an uneven surface 63 formed on the press fit wall 15 of the metallic tube 11. The whole of the uneven surface 63 is patterned with latticed lines 6 in knurling, for example. Other arrangements are identical with those in the first embodiment.

[0056] Fig. 7 shows the second embodiment of the invention which has formed on the small-diameter inner wall 55 of the housing 5 an uneven surface 64 instead of the uneven surface 60 on the press fit wall 15 of the heater 10 in the first embodiment. The uneven surface 64 has formed thereon the scratches 6 in the same pat-

tern as that of the first embodiment. The housing 5 is made from material having the hardness greater than that of the heater 10. Other arrangements are identical with those in the first embodiment.

[0057] Fig. 8 shows the first modification of the second embodiment which has an uneven surface 65 formed on the small-diameter inner wall 55 of the housing 5. The uneven surface 65 is patterned with a spiral line 6 using a cutting tool. Other arrangements are identical with those of the second embodiment.

[0058] Fig. 9 shows the second modification of the second embodiment which has an uneven surface 66 formed on the small-diameter inner wall 55 of the housing 5. The uneven surface 66 is patterned with latticed lines 6 in knurling, for example. Other arrangements are identical with those of the second embodiment.

[0059] While the above described patterns on the press fit wall 15 of the metallic tube 11 and the small-diameter inner wall 55 of the housing 5 are defined by fine grooves, they may alternatively be formed with fine protrusions or ridges. In this case, the press-fitting of the heater 10 into the housing 5 causes the ridges to be forced into the small-diameter inner wall 55 or the press fit wall 15, whichever is the softer, to form barriers which establish airtight engagement between the heater 10 and the housing 5.

[0060] Fig. 10 shows the third embodiment of the glow plug 1 which has a heater 10 different in structure from the ones in the above embodiments.

[0061] The heater 10 has a metallic tube 11. The metallic tube 11 includes a guide stem 17 which is smaller in diameter than the press fit wall 15 and extends from the press fit wall 15 through a tapered wall 16. Other arrangements are identical with those of the first embodiment, and explanation thereof in detail will be omitted here.

[0062] In assembly of the glow plug 1, the metallic tube 11 and the central rod 4 to which the end 32 of the heating coil 3 is attached are first prepared. Next, the heating coil 3 is inserted into the metallic tube 11 and welded at the end 31 to the inner wall of the head 111 of the metallic tube 11.

[0063] The insulating powder 2 made of magnesia (MgO) is packed into the metallic tube 11 to insulate the heating coil 3 and the head 41 of the central rod 4 from the inner wall of the metallic tube 11.

[0064] The metallic tube 11 is swaged to decrease the diameter thereof, thereby increasing the density of the insulating powder 2 in the metallic tube 11 to hold the central rod 4 in the heater 10 tightly.

[0065] A base portion of the metallic tube 11, as indicated by a broken line in Fig. 11, is ground or machined with a cutting tool to form the press fit wall 15, the tapered wall 16, and the guide stem 17. The swaging usually causes the overall length of the metallic tube 11 to change, but the length L from the head 111 of the metallic tube 11 to a lower end of the press fit wall 15, as viewed in the drawing, is fixed, whil the length of the guide stem 17 is changed in ,accordance with the change in overall length of the metallic tube 11. It is advisable that the location of the pass wall 15 from the head 111 of the metallic tube 11 be determined under the condition that the guide stem 17 has a length of 3 mm or more for ensuring alignment of the heater 10 with the housing 5 when they are joined temporarily.

[0066] The uneven surface 60 is formed in the same manner as that in either of the first and second embodiments.

[0067] Next, the housing 5 is, as shown in Fig. 12, prepared. The heater 10 is forced into the housing 5 in a manner as discussed below.

[0068] The housing 5 has, as described above, the tapered surface 56 formed by chamfering an edge of the small-diameter inner wall 55 facing the heater insertion opening 51. An inclination β of the tapered surface 56 relative to the longitudinal center line of the housing 6 is, as clearly shown in Fig. 13, greater than an inclination α of the tapered wall 16 of the heater 10 ($\alpha < \beta < 45°$).

[0069] The housing 5 is, as shown in Fig. 12, placed on the holder 86 with the heater insertion opening 51 facing upward. The holder 86, unlike a conventional structure wherein the housing 5 is retained horizontally, has formed therein a through hole 860 coaxially with the cylindrical bore 50 of the housing 5. The through hole 860 has the diameter greater than the outer diameter of the central rod 4, but smaller than the outer diameter of the housing 5.

[0070] Next, the central rod 4 of the heater 10 is, as shown in Fig. 14, inserted into the cylindrical bore 50 of the housing 5 to join the heater 10 and the housing 5 temporarily. When the heater 10 is in misalignment with the housing 5 at the insertion, it is corrected by sliding movement of the tapered wall 16 of the heater 10 along the tapered surface 56 of the housing 5 toward the small-diameter inner wall 55.

[0071] After aligned with the housing 5, the heater 10 is, as shown in Fig. 15, pressed by the press block 81 downward to bring the press fit wall 15 into tight engagement with the small-diameter inner wall 55, thereby forming barriers establishing airtight engagement between the metallic tube 11 and the housing 5 in the same manner as that in the first embodiment.

[0072] Finally, the nut 71, the resinous bush 72, the O-ring 73, and the resinous washer 74 are installed in and on the end of the housing 5 to hold the central rod 4 hermetically within the housing 5.

[0073] The central rod 4 is retained by the guide stem 17 of the metallic tube 11 through the packed insulating powder 2. The guide stem 17, as described above, extends from the press fit wall 15 through the tapered wall 16. Therefore, even when the press fit wall 15 is forced into the cylindrical bore 50 so that it decreases in diameter by the tight engagement with the small-diameter inner wall 55 of the housing 5, the guide stem 17 is hardly decreased in diameter, ther by keeping the insulation of th central rod 4 from th metallic tube 11.

[0074] In case, where the press fit wall 15 has a desired roundness after the metallic tube 11 is swaged the press fit wall 15 may, as shown in Fig. 16, be formed flush with a major portion of the metallic tube 11 without being ground after the metallic tube 11 is swaged.

[0075] Fig. 17 shows the first modification of the press-fitting operation to force the heater 10 into the housing 5 in the third embodiment.

[0076] After the housing 5 to which the heater 10 is joined temporarily is, as shown in Fig. 14, placed on the holder 86, the periphery of the heater 10 is, as shown in Fig. 17, held by a collet 6.

[0077] The collet 6, as shown in Figs. 18 to 20, has a coned sleeve 69 which is split by slits 63 to form three jaws 61 arranged radially. The sleeve 69 has a heater holding hole 60 formed in the center of the bottom to define arc-shaped surfaces 62 curved with a curvature substantially equal to that of the periphery of the heater 10 for maximizing an area of contact with the periphery of the heater 10, thereby avoiding local concentration of pressure on the periphery of the heater 10 during insertion into the housing 5. The collet 6 may alternatively have four jaws 61, as shown in Fig. 21.

[0078] The attachment of the heater 10 to the collect 6 is, as shown in Fig. 17, achieved by drawing the collet 6 into a jig 7 using the hydraulic pressure, for example, to squeeze the jaws 61, grasping the heater 10. A maximum pressure exerted by the collet 6 to force the heater 10 into the housing 5 depends upon the friction between the collet 6 and the metallic tube 11 and may be adjusted by controlling the pressure acting on the jaws 61 radially of the collet 6.

[0079] Next, the heater 10 held by the collet 6 is, as shown in Fig. 17, forced downward using a press machine (not shown) to bring the press fit wall 15 of the heater 10 into tight engagement with the small-diameter inner wall 55 of the housing 5.

[0080] Other processes are identical with those in the third embodiment, and explanation thereof in detail will be omitted here.

[0081] Fig. 22 shows the second modification of the press-fitting operation to force the heater 10 into the housing 5 in the third embodiment.

[0082] The collect 6 includes a push rod 68 producing additional pressure acting on the heater 10 during insertion into the housing 5. The push rod 68 includes a threaded portion 682 and a stem 689. The threaded portion 682 meshes with internal threads 64 formed in an inner wall of the collet 6. The stem 689 has a head 681 curved inwardly so as to fit with the round head 111 of the heater 10.

[0083] The attachment of the heater 10 to the housing 5 is achieved in the following manner. The heater 10 is first held by the collet 6. The push rod 68 is screwed into the collet 6 until it is touched to the head 111 of the heater 10 without urging the heater 10 downward. A grasp of the heater 10 is so adjusted that a maximum friction between the collet 6 and the heater 10 will be F1 (i.e., 5 kN).

[0084] Next, downward load is applied to the collet 6 through a press machine (not shown) in accordance with load lines shown in Fig. 23. In Fig. 23, a line A indicates a load transferred from the collet 6 to the heater 10, a line B indicates a load transferred from the push rod 68 to the heater 10, and a line C indicates the sum of loads transferred from the collet 6 and the push rod 68.

[0085] As can be seen from Fig. 23, in an initial stage of the press operation, the load is applied to the heater 10 only from the collet 6, as shown by the line A. When the load exerted by the collet 6 on the heater 10 reaches F1 that is the maximum friction between the collet 6 and the heater 10, it will be constant without increasing. The heater 10 begins to slip so that it is urged against the head 681 of the push rod 68, thereby causing the load exerted by the push rod 68 on the heater 10 to be increased, as shown by the line B. The press operation is completed when the total load, as shown by the line C, reaches 10 kN.

[0086] The press operation of this embodiment applies a load of 5 kN to the heater 10 through each of the collet 6 and the push rod 68. In other words, a load of 5 kN acts, in sequence, on different portions of the heater 10. This further reduces local concentration of pressure on the heater 10 during the press operation as compared with the above embodiments.

[0087] Fig. 24 shows the third modification of the press-fitting operation to force the heater 10 into the housing 5 in the third embodiment.

[0088] This modification uses first and second collets 65 and 66 which have formed therein central openings to define arc-shaped surfaces 652 and 662, respectively, similar to the collect 6 shown in Fig. 17. The first and second collets 65 and 66 are disposed vertically at a given interval and apply different loads to the heater 10 downward in accordance with load lines shown in Fig. 25. In Fig. 25, a line D indicates a load transferred from the first collet 65 to the heater 10, a line E indicates a load transferred from the second collet 66 to the heater 10, and a line F indicates the sum of loads transferred from the first and second collets 65 and 66. A radio of the load exerted from the first collet 65 on the heater 10 to the load exerted from the second collet 66 on the heater 10 is 1.3 : 1. Specifically, a greater load is provided by the first collet 65 located near the press fit wall 15 of the heater 10, while a smaller load is provided by the second collet 66 located far from the press fit wall 15, thereby avoiding bending or breakage of the heater 10 during the press-fitting operation.

[0089] Fig. 26 shows the fourth modification of the press-fitting operation to force the heater 10 into the housing 5 in the third embodiment.

[0090] This modification uses a first collet 65 and a second collet 66 disposed within the first collet 65. The first collet 65 has a coned sleeve 69 which is, similar to the one shown in Fig. 18, split by slits to form jaws 651

arranged radially. The sleeve 69 has a heater holding hole 650 formed in the center of the bottom to define arc-shaped surfaces 652 curved outwardly with a curvature substantially equal to that of the periphery of the heater 10 for maximizing an area of contact with the periphery of the heater 10, thereby avoiding local concentration of pressure on the periphery of the heater 10 during insertion into the housing 5. The first collet 65 has formed therein a tapered bore 654 in alignment with the heater insertion hole 650 within which the second collet 66 is mounted.

[0091] The second collet 66, like the first collet 65, has a coned sleeve 71 split by slits to form jaws 661 arranged radially. The sleeve 71 has a heater holding hole 660 formed in the center of the bottom to define arc-shaped surfaces 662 similar to the first collet 65 and also has a tapered outer surface 664 contouring an inner wall of the tapered bore 654 of the first collet 65.

[0092] The first collect 65 is designed to be drawn into a jig 67 by hydraulic pressure to squeeze the jaws 651, grasping the heater 10 in tight engagement of the arc-shaped surfaces 652 with the periphery of the heater 10. The second collet 66 is designed to be forced into the tapered bore 654 of the first collet 65 by air or hydraulic pressure to squeeze the jaws 661, grasping a head portion of the heater 10.

[0093] Downward loads applied from the first and second collets 65 and 66 to the heater 10 are adjusted by controlling the air and hydraulic pressures acting on the first and second collets 65 and 66 and may be determined similar to the third modification as described above.

[0094] Fig. 27 shows the fourth embodiment of the glow plug 1 which has a heater 10 different in structure from the ones in the above embodiments.

[0095] The metallic tube 11 has formed thereon the press fit wall 15 whose diameter is substantially equal to that of a major portion of the metallic tube 11. A cylindrical sealing member 90 is disposed within the open end 112 of the metallic tube 11 which has the thickness T (3 mm in this embodiment), as shown in Fig. 29, smaller than the length L (20 mm in this embodiment) of a head portion of the central rod 4 embedded in the insulating powder 2.

[0096] Other arrangements are identical with those in the first embodiment, and explanation thereof in detail will be omitted here.

[0097] In assembly of the glow plug 1, the metallic tube 11 and the central rod 4 to which the end 32 of the heating coil 3 is attached are first prepared. Next, the heating coil 3 is, as shown in Fig. 28(a), inserted into the metallic tube 11 and connected at the end 31 to the inner wall of the head 111 of the metallic tube 11 by plasma welding.

[0098] The insulating powder 2 made of magnesia (MgO) is packed into the metallic tube 11 and subjected to vibrations to increase the density thereof.

[0099] A sealing liquid 80 is, as shown in Fig. 28(b), put on the insulating powder 2 in the metallic tube 11 The sealing liquid 80 is an air-hardening, thermo-hardening, or ultraviolet-hardening liquid such as silicone rubber, fluoro rubber, acrylate resin, phloro silicone rubber, NBR rubbers, hydrin rubbers, and epoxy rubbers having a viscosity of 50 to 10000 St. This embodiment uses the liquid silicone rubber having a viscosity of 250 St.

[0100] After put in the metallic tube 11, the sealing liquid 80 is left as it is at room temperature for 5 hours or more. This causes, as shown in Fig. 28(c), the sealing liquid 80 to permeate the insulating powder 2 and to be hardened, thereby forming the sealing member 90. The part of the sealing liquid 80 left on the insulating powder 2 is hardened as it is to form a sealing layer 85. The sealing member 90 and the sealing layer 85 serve to avoid entrance of air or oil into the metallic tube 11.

[0101] Next, the metallic tube 11 is swaged to decrease the diameter thereof to a desired value. This causes the density of the insulating powder 2 in the metallic tube 11 to be increased and the overall length of the metallic tube 11 to be prolonged with the result that the sealing member 90 and the sealing layer 85, as shown in Fig. 29, increase in thickness slightly. If the sealing layer 85 is, as shown in Fig. 30, forced out of the metallic tube 11, it may be either removed or left as it is.

[0102] Other assembling process are identical with those in the first embodiment, and explanation thereof in detail will be omitted here.

[0103] Fig. 31 represents the permeability of the sealing member 90 measured for different values of thickness thereof.

[0104] It is known by experience that a sealing member having a permeability of 10^{-5}cc/sec · kg/cm^2 or less is not objectionable in practical use of glow plugs. Fig. 31, thus, shows that it is advisable that the thickness T of the sealing member 90 be 0.5 mm or more when the sealing member 90 is made from liquid silicone rubber.

[0105] Fig. 32 represents the relation between depth of a portion of the insulating powder 2 into which the sealing liquid 80 penetrates (i.e., the thickness of the sealing member 90), which will be referred to as sealing liquid-penetrated depth below, and viscosity of the sealing liquid 80.

[0106] Four types of sealing liquid having different viscosities of 50, 250, 1000, and 10000 St were put in the metallic tube 11. The sealing liquid-penetrated depth was measured for a given period of time for each type of sealing liquid. As can be seen from Fig. 32, the sealing liquid-penetrated depth for each type of sealing liquid will be constant after a certain period of time has lapsed. It is, thus, found that the adjustment of the thickness of the sealing member 90 may be achieved by changing the viscosity of the sealing liquid 80.

[0107] It is, as described above, advisable that the thickness T of the sealing member 90 in the structure shown in Fig. 27 be 0.5 mm or more in case where the sealing member 90 is made from liquid silicone rubber.

Fig. 32 shows that the use of the sealing liquid 80 having a viscosity of 50 to 10000 St allows the sealing member 90 having a thickness of 0.5 mm or more to be formed.

[0108] While the present invention has been disclosed in terms of the preferred embodiment in order to facilitate a better understanding thereof, it should be appreciated that the invention can be embodied in various ways without departing from the principle of the invention. Therefore, the invention should be understood to include all possible embodiments and modification to the shown embodiments which can be embodied without departing from the principle of the invention as set forth in the appended claims.

[0109] An improved sealing structure of a glow plug for diesel engines is provided. The glow plug includes a heater assembly which consists of a heater casing, a heating element, and a power supply rod. The heater casing has disposed therein the heating element connecting with the power supply rod and also has formed on a periphery thereof a press fit wall press-fitted into a hollow housing in tight engagement with an inner peripheral wall of the hollow housing. An uneven surface is formed on one of the press fit wall of the heater casing and the inner peripheral wall of the hollow housing. The uneven surface is patterned with lines such as fine grooves or ridges oriented at an angle relative to a longitudinal center line of the glow plug for forming barriers when the press fit wall is forced into the hollow housing which establish airtight seals between the heater casing and the hollow housing.

Claims

1. A glow plug comprising:

   a hollow housing having a given length;
   a heater assembly including a heater casing, a heating element, and a power supply rod, the heater casing having disposed therein the heating element connecting with the power supply rod and also having formed on a periphery thereof a press fit wall press-fitted into said hollow housing in tight engagement with an inner peripheral wall of said hollow housing; and
   an uneven surface formed on one of the press fit wall of said heater casing and the inner peripheral wall of said hollow housing, said uneven surface having formed thereon a pattern which has a length oriented at an angle relative to a longitudinal center line of the glow plug.

2. A glow plug as set forth in claim 1, wherein said uneven surface has a surface roughness of 25 µm or less (Rz).

3. A glow plug as set forth in claim 1 or 2, wherein said uneven surface occupies 20% or more of an area of one of the press fit wall of said heater casing and the inner peripheral wall of said hollow housing.

4. A glow plug as set forth in any one of claims 1 to 3, wherein said uneven surface is patterned with lines.

5. A glow plug as set forth in claim 4, wherein the lines of said uneven surface are oriented at 30° or more relative to the longitudinal center line of the glow plug.

6. A glow plug as set forth in claim 4, wherein the lines of said uneven surface are formed with one of fine grooves and protrusions.

7. A glow plug as set forth in any one of claim 1 to 6, wherein the press fit wall of said heater casing has a hardness different from that of the inner peripheral wall of said hollow housing.

8. A glow plug as set forth in any one of claims 1 to 7, further comprising an insulating powder disposed within the heater casing to insulate the heating element from the heater casing and a sealing member, and wherein the heating casing has a given length and has formed therein an open end, the power supply rod is partially inserted into the insulating powder through the open end of the heating casing, and the sealing member is made of a sealing liquid which is penetrated into a portion of the insulating powder exposed to the open end of the heater casing and which is hardened to form an airtight seal in the open end of the heater casing.

9. A glow plug as set forth in claim 8, wherein the thickness of the sealing member is smaller than the length of a portion of the power supply rod embedded into the insulating powder.

10. A glow plug as set forth in claim 8 or 9, wherein the sealing member has a permeability of 10^{-5}cc/sec · kg/cm^2 or less.

11. A glow plug as set forth in any one of claim 8 to 10, wherein the sealing member is made of a silicone rubber.

12. A glow plug as set forth in any one of claims 8 to 11, wherein the thickness of the sealing member is 0.5 mm or more.

13. A glow plug production method comprising the steps of:

    preparing a hollow housing having a given length;

preparing a heater assembly including a heater casing and a heating element disposed within the heater casing, the heater casing having a press fit wall formed on a periphery thereof;

machining one of the press fit wall of the heater casing and the inner peripheral wall of said hollow housing so as to form an uneven surface with a pattern which has a length oriented at an angle relative to a longitudinal center line of said hollow housing; and

forcing the heater casing of said heater assembly into said hollow housing to establish tight engagement between the press fit wall of the heater casing and the inner peripheral wall of said hollow housing.

14. A glow plug production method as set forth in claim 13, wherein said machining step patterns the uneven surface with lines formed with one of fine grooves or protrusions.

15. A glow plug production method as set forth in claim 13, further comprising a machining step of, before forcing the heater casing into said hollow housing, machining an end portion of the heater casing which is to be inserted into said hollow housing to form a guide stem having a diameter smaller than that of the inner peripheral wall of said hollow housing and a tapered wall connecting the press fit wall and the guide stem.

16. A glow plug production method as set forth in claim 15, wherein the guide stem has a length of 3 mm or more.

17. A glow plug production method as set forth in claim 13, further comprising a forming step of forming a tapered inner wall in said hollow cylinder oriented at an angle relative to the longitudinal center line of said hollow cylinder which is greater than an angle at which the tapered wall of the heater casing is oriented relative to a longitudinal center line of the heater casing.

18. A glow plug production method as set forth in claim 13, wherein said forcing step includes a grasping step of grasping a periphery of the heater casing using a collet and a pressing step of pressing the collect to force the heater casing of said heater assembly into said hollow housing.

19. A glow plug production method as set forth in claim 18, wherein said forcing step further includes a mounting step of, before the pressing step, mounting the heater casing in said hollow housing in alignment.

20. A glow plug production method as set forth in claim 18, wherein said forcing step further includes a second pressing step of pressing a head of the heater casing using a press member after a load applied to the heater casing from the collet reaches a given level.

21. A glow plug production method as set forth in claim 13, wherein said forcing step includes a grasping step of grasping axially spaced peripheral portions of the heater casing using a first and a second collet and a pressing step of pressing the first and second collets under different pressures, respectively, to force the heater casing of said heater assembly into said hollow housing.

22. A glow plug production method comprising the steps of:

preparing a hollow housing having a given length;

preparing a heater assembly including a heater casing and a heating element disposed within the heater casing, the heater casing having a press fit wall formed on a periphery thereof;

machining an end portion of the heater casing to form a guide stem having a diameter smaller than that of an inner peripheral wall of said hollow housing and a tapered wall connecting the press fit wall and the guide stem; and

forcing the end portion of the heater casing into said hollow housing to establish tight engagement between the press fit wall of the heater casing and the inner peripheral wall of said hollow housing.

23. A glow plug production method as set forth in claim 22, further comprising a forming step of forming a tapered inner wall in said hollow cylinder oriented at an angle relative to the longitudinal center line of said hollow cylinder which is greater than an angle at which the tapered wall of the heater casing is oriented relative to a longitudinal center line of the heater casing.

24. A glow plug production method comprising the steps of:

preparing a hollow housing having a given length;

preparing a heater assembly including a heater casing, a heating element, and a power supply rod, the heater casing having disposed therein the heating element connecting with the power supply rod and also having formed on a periphery thereof a press fit wall;

grasping a periphery of the heater casing with arc-shaped surfaces of jaws of a collet; and

pressing th collect to force the heater casing

of said heater assembly into said hollow housing to establish tight engagement between the press fit wall of the heater casing and an inner peripheral wall of said hollow housing.

25. A glow plug production method as set forth in claim 24, further comprising a second pressing step of pressing a head of the heater casing using a press member after a load applied to the heater casing from the collet reaches a given level.

26. A glow plug production method as set forth in claim 24, wherein said grasping step grasps axially spaced peripheral portions of the heater casing using a first and a second collet and wherein said pressing step presses the first and second collets under different pressures, respectively, to force the heater casing of said heater assembly into said hollow housing.

27. A glow plug comprising:

a hollow housing having a given length;
a heater assembly including a heater casing, a heating element, and a power supply rod, the heater tube having disposed therein the heating element connecting with the power supply rod partially inserted into the heater tube through an open end and also having formed on a periphery thereof a press fit wall press-fitted into said hollow housing in tight engagement with an inner peripheral wall of said hollow housing;
an insulating powder disposed within the heater tube to insulate the heating element from the heater tube; and
a sealing member made of a sealing liquid which is penetrated into a portion of the insulating powder exposed to the open end of the heater tube and which is hardened to form an airtight seal in the open end of the heater casing.

28. A glow plug as set forth in claim 27, wherein the sealing member has a permeability of 10^{-5}cc/sec • kg/cm^2 or less.

29. A glow plug production method comprising the steps of:

preparing a hollow housing having a given length;
preparing a heater assembly including a metallic heater tube, a heating element, a power supply rod, and an insulating powder, the heater tube having disposed therein the heating el ment connecting with the power supply rod partially inserted into the heater tube through an open end and also having formed on a periphery thereof a press fit wall, the insulating powder being disposed within the heater tube to insulate the heating element from the heater tube;
penetrating a sealing liquid into a portion of the insulating powder exposed to the open end of the heater tube and hardening the sealing liquid to form an airtight seal in the open end of the heater casing;
swaging the heater tube to decrease a diameter thereof; and
forcing the heater tube into said hollow housing to establish tight engagement between the press fit wall of the heater tube and the inner peripheral wall of said hollow housing.

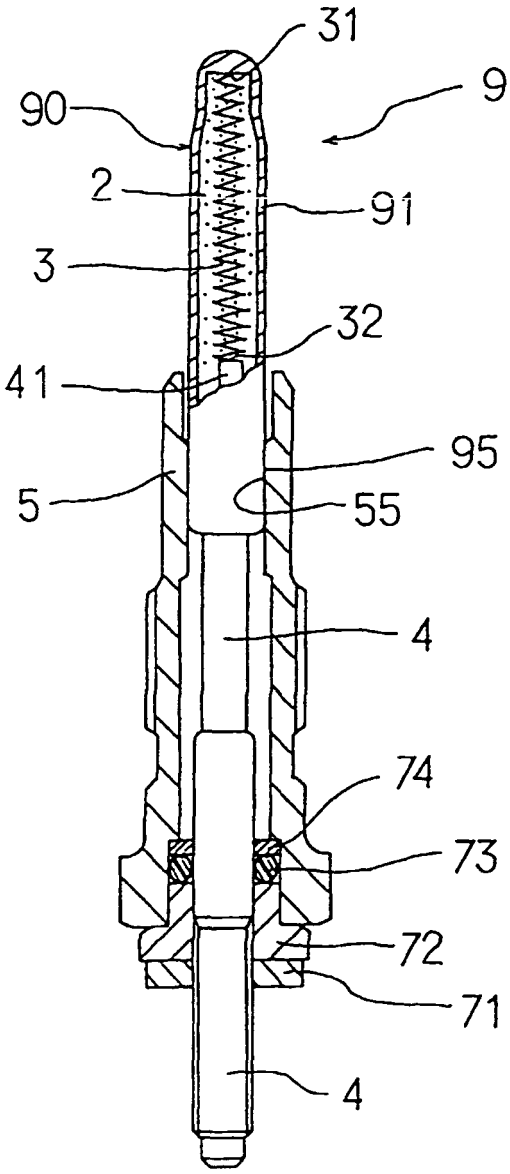

FIG. 1

PRIOR ART

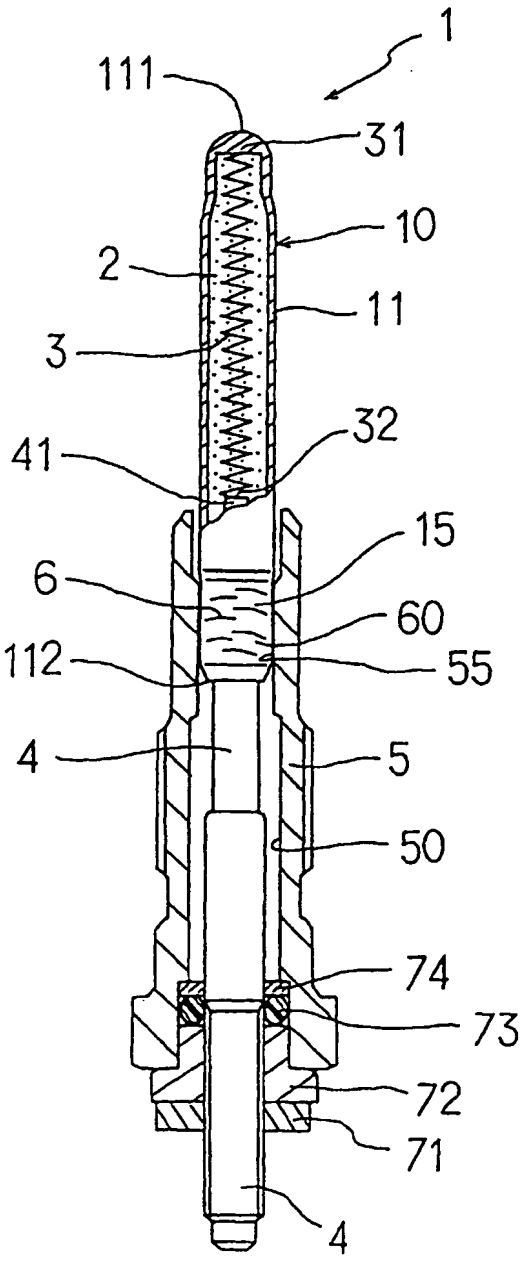

FIG. 2

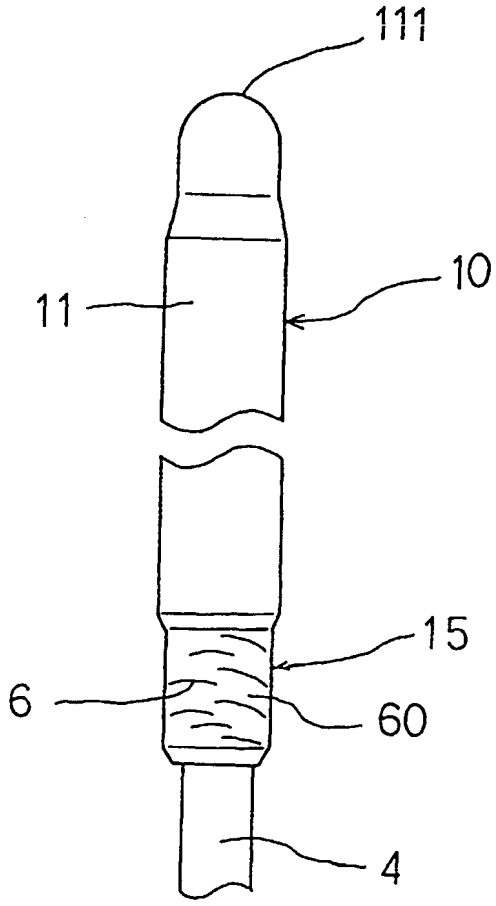

FIG. 3

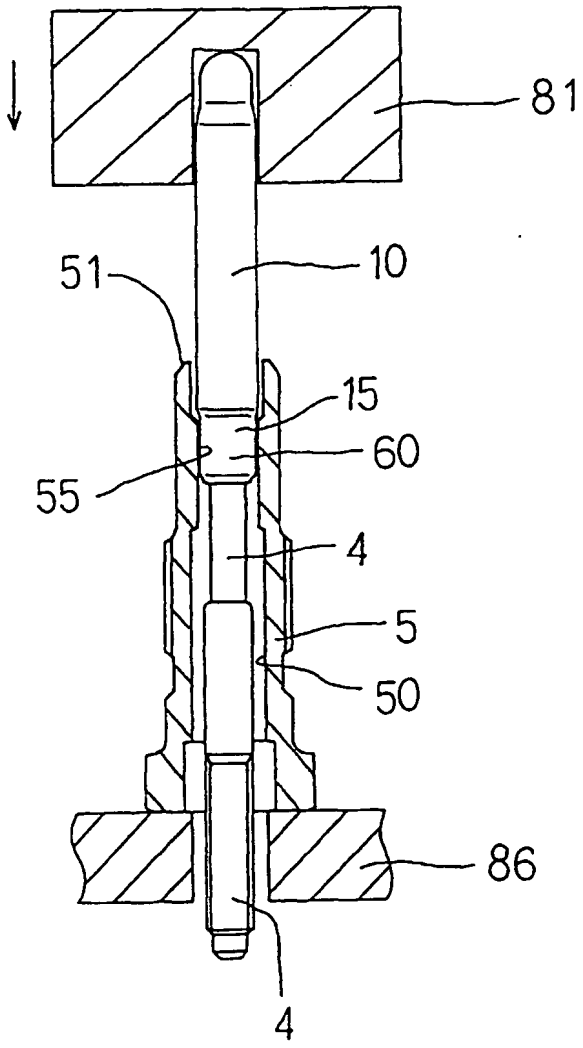

FIG. 4

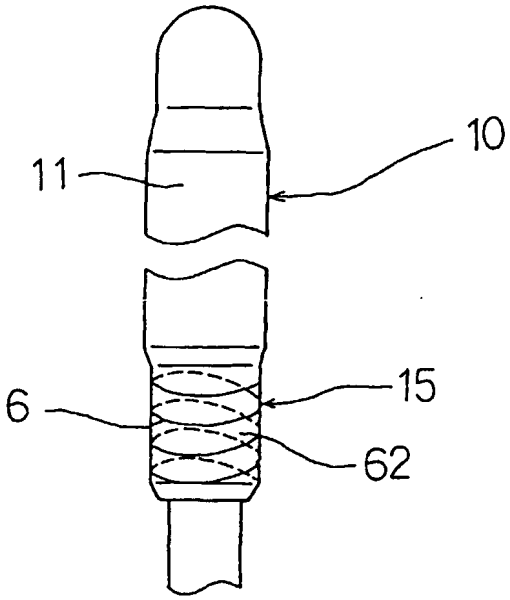

FIG. 5

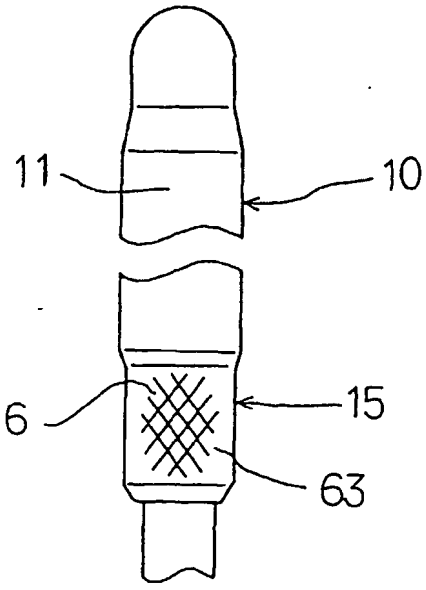

FIG. 6

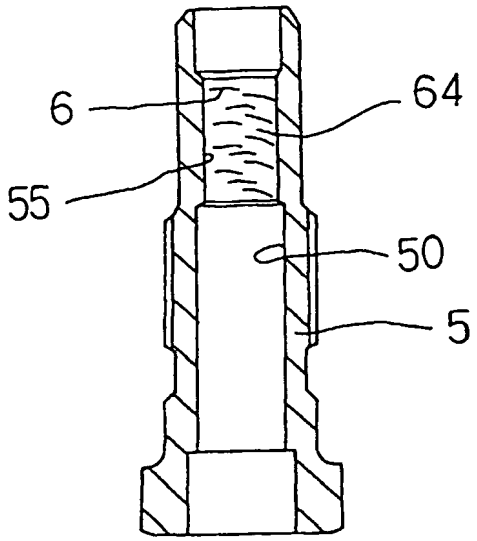

FIG. 7

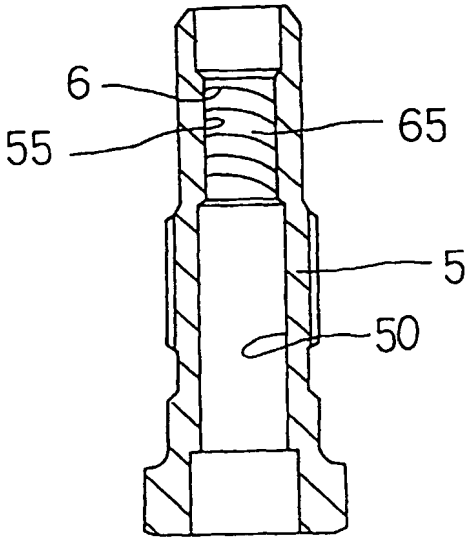

FIG. 8

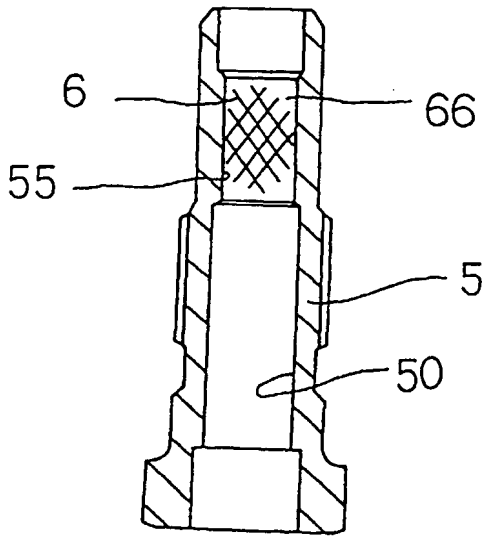

FIG. 9

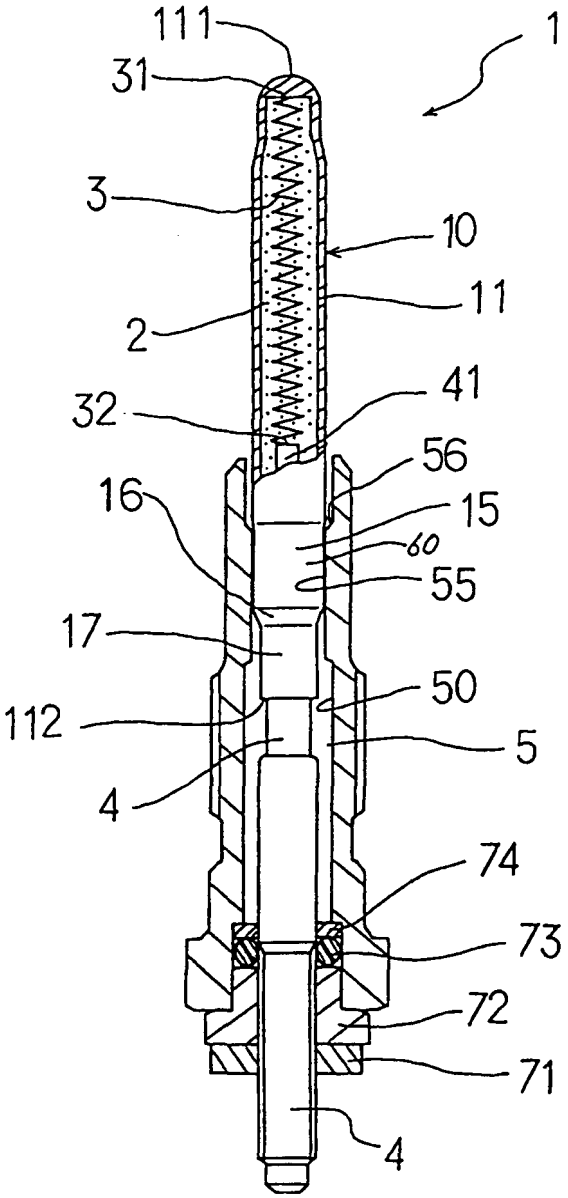

FIG. 10

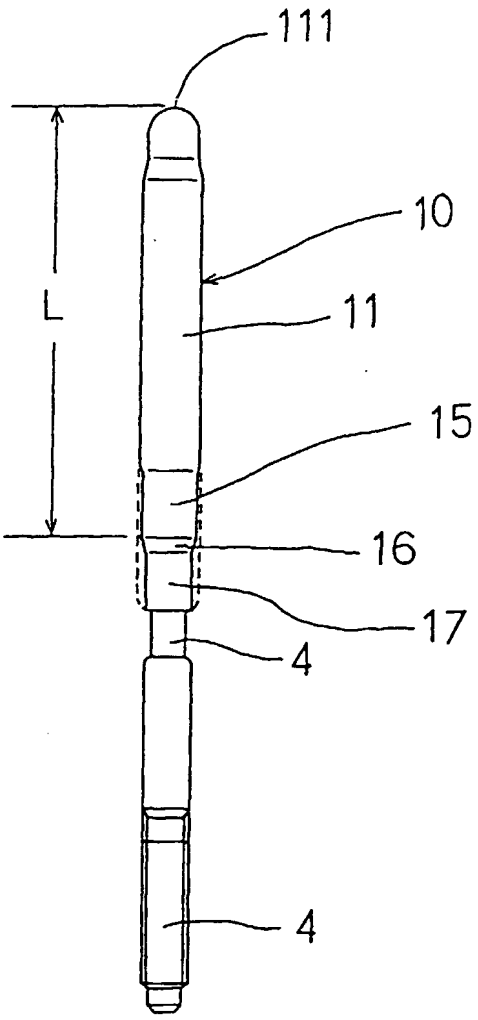

FIG. 11

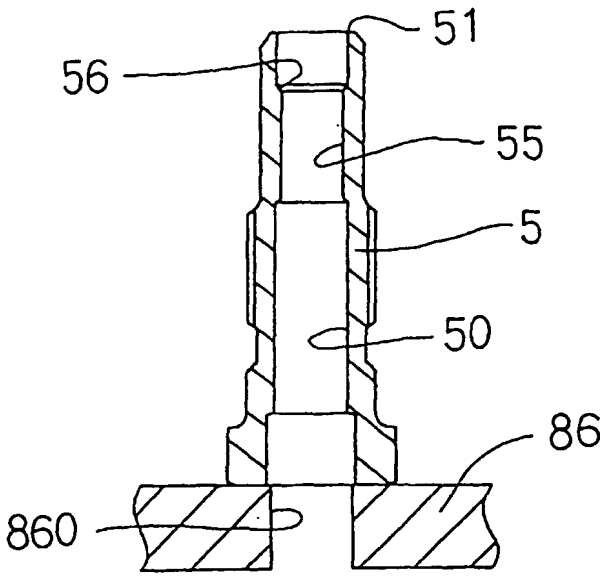

FIG. 12

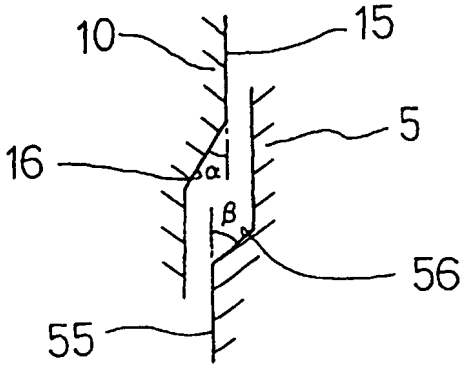

FIG. 13

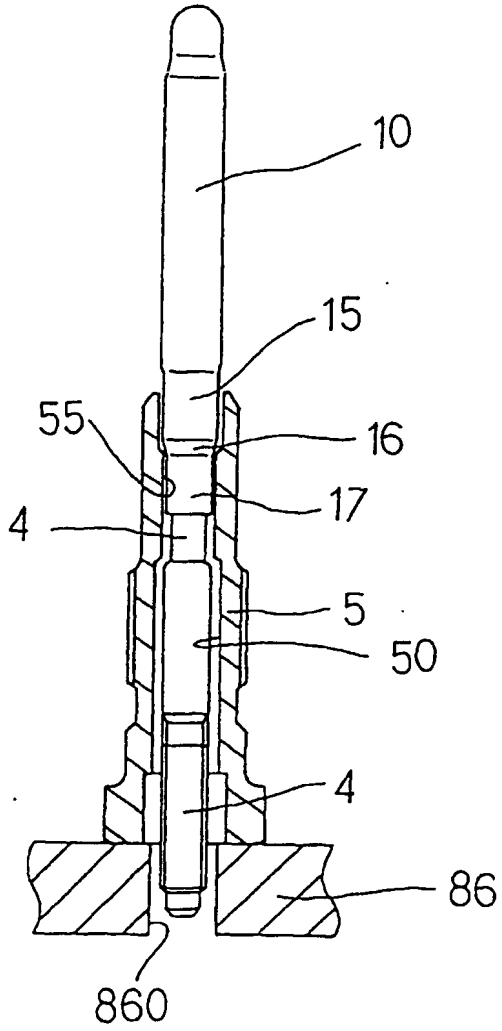

FIG. 14

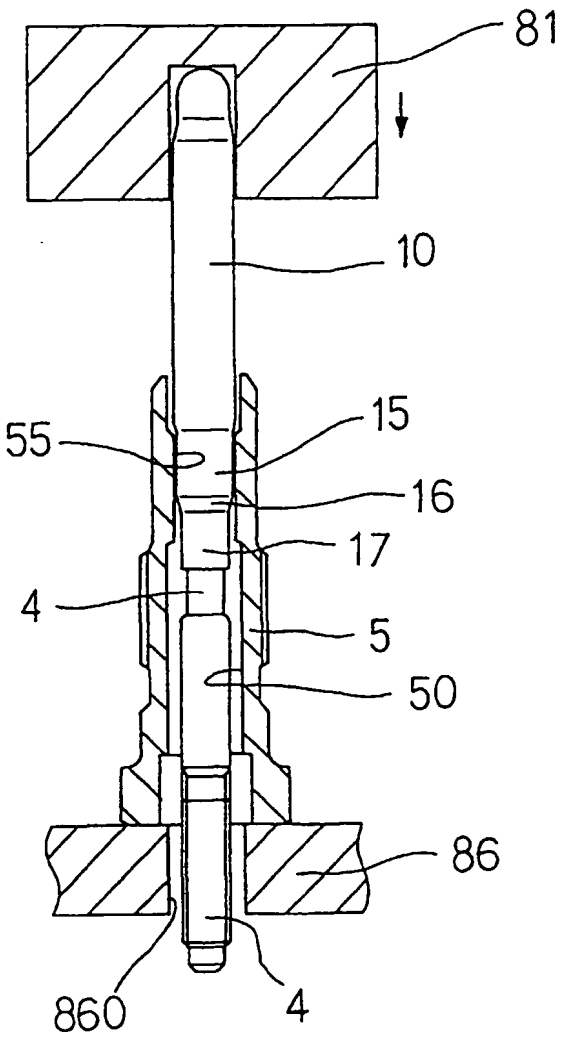

FIG. 15

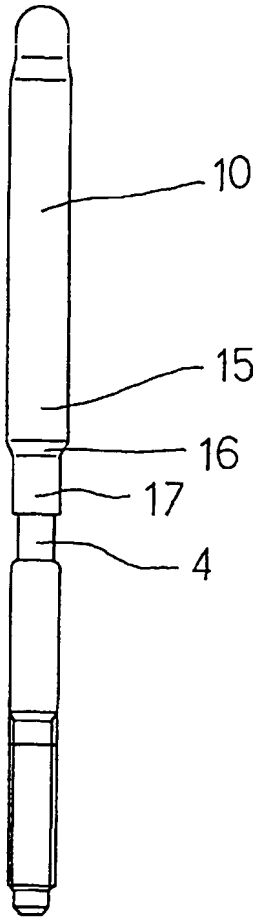

FIG. 16

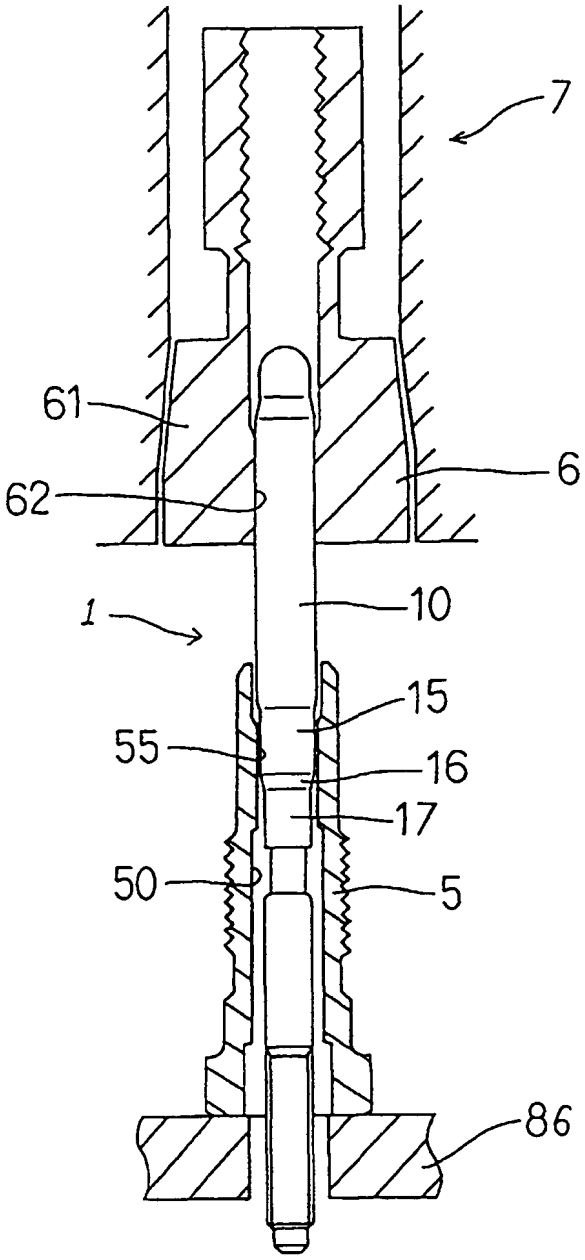

FIG. 17

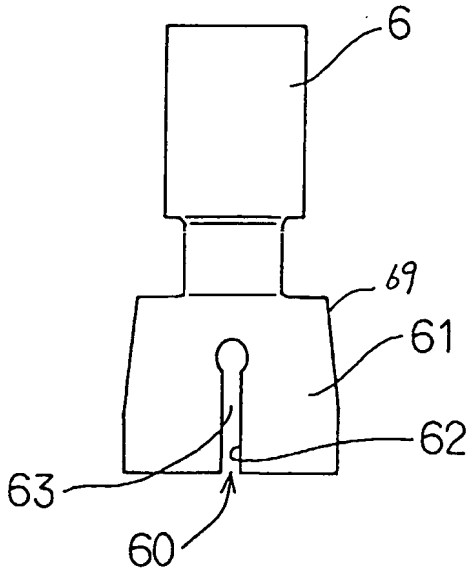

FIG. 18

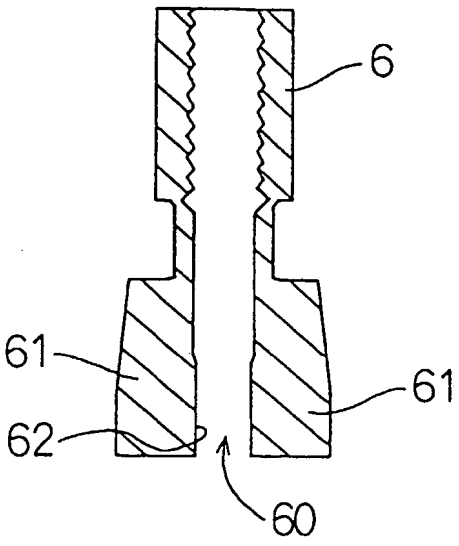

FIG. 19

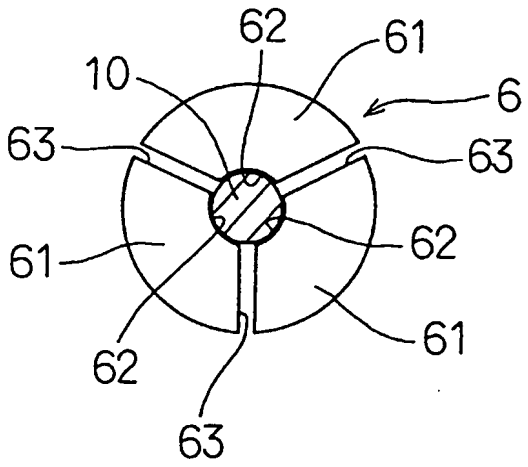

FIG. 20

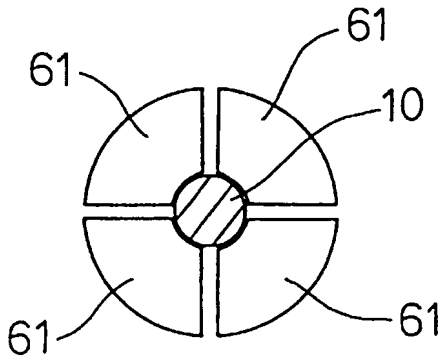

FIG. 21

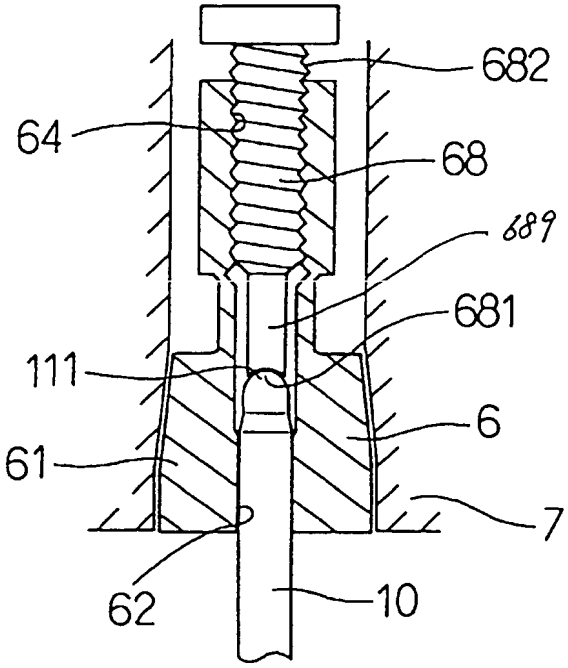
682
64
68
689
681
111
6
61
7
62
10

FIG. 22

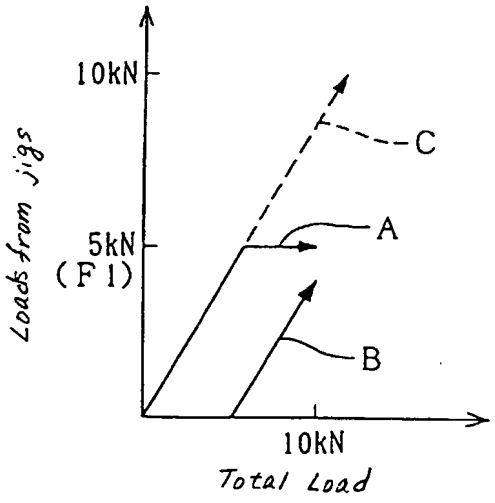
10kN
Loads from jigs
5kN
(F1)
C
A
B
10kN
Total Load

FIG. 23

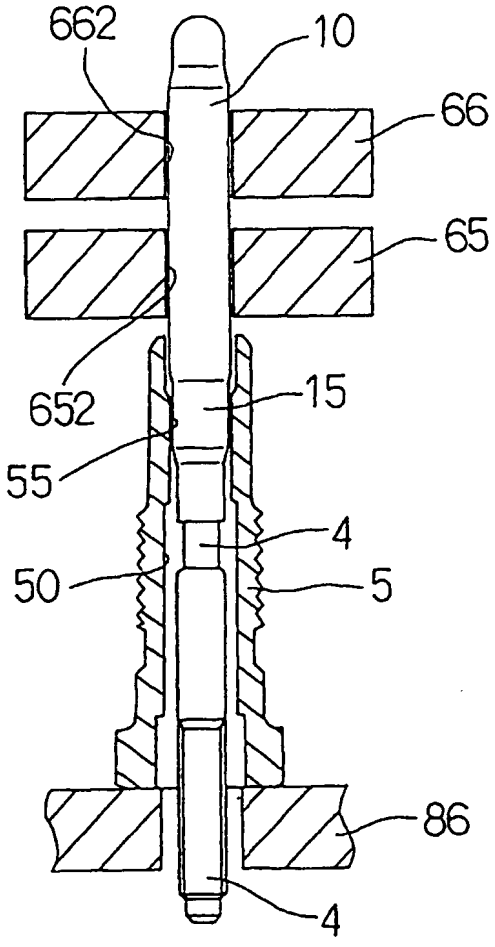

FIG. 24

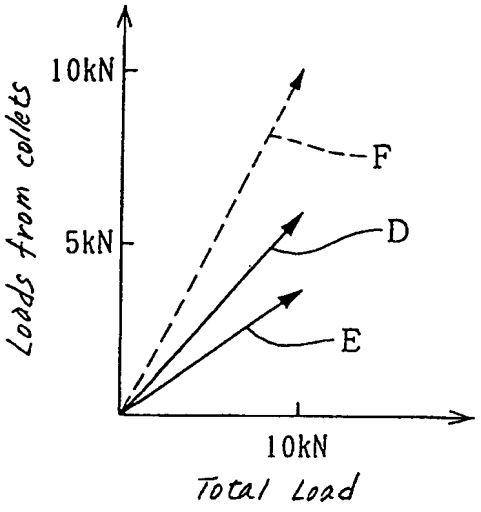

FIG. 25

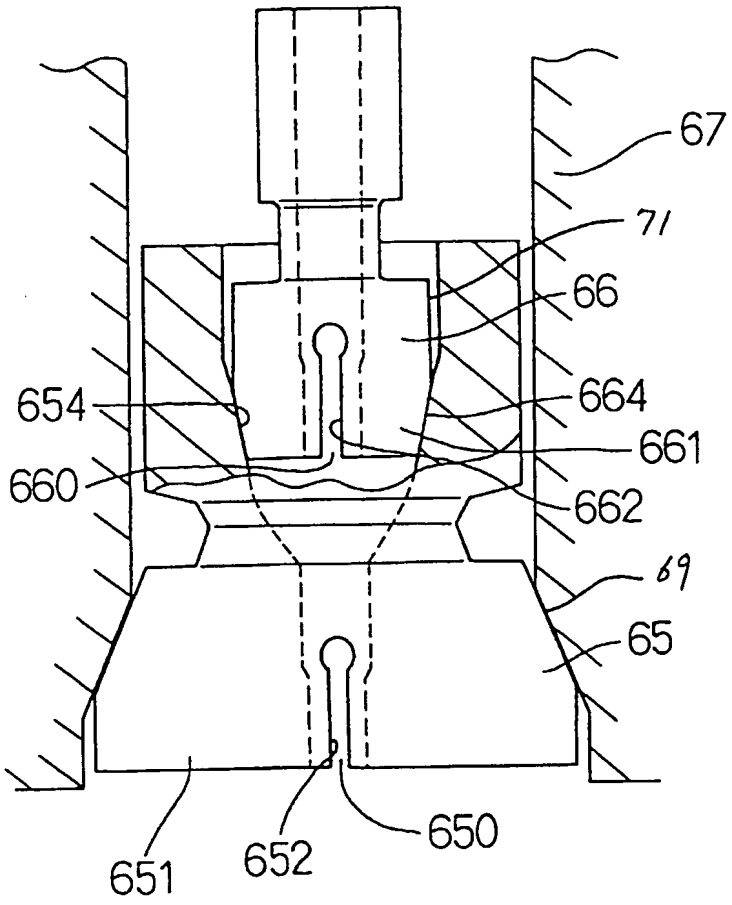

FIG. 26

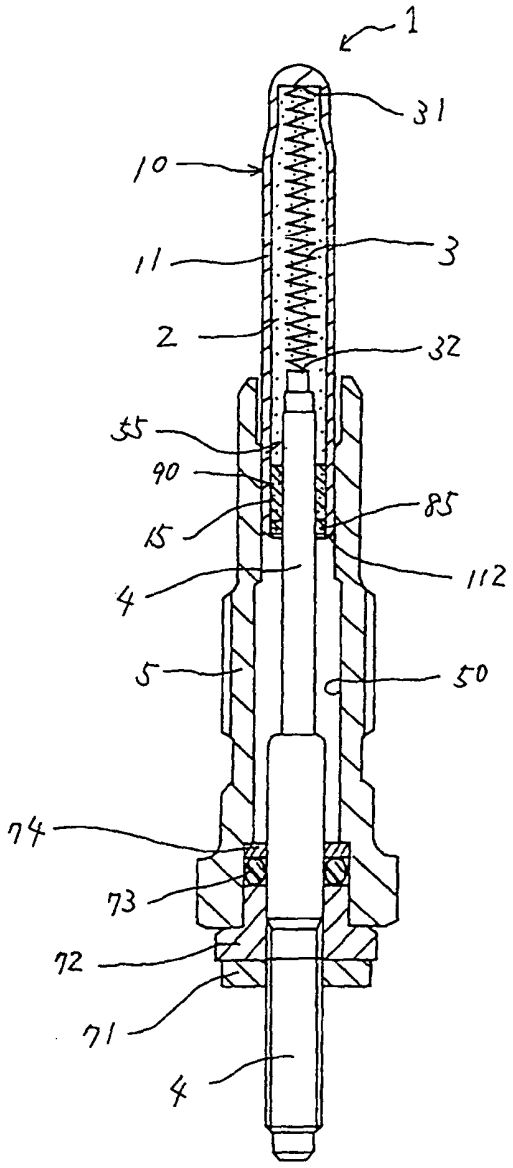

FIG.27

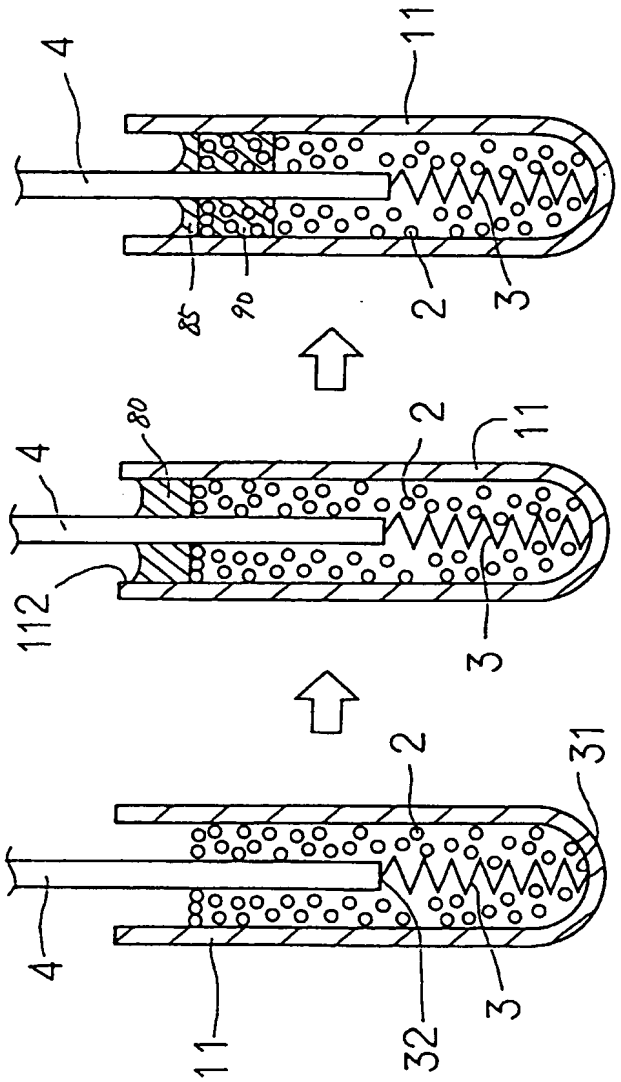

FIG. 28(a)

FIG. 28(b)

FIG. 28(c)

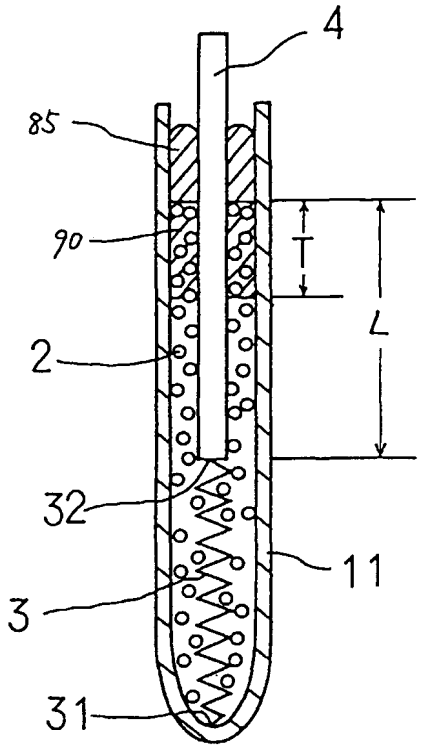

FIG. 29

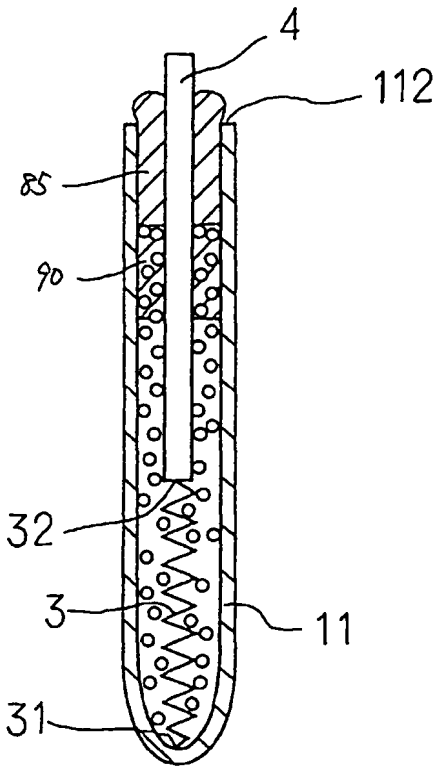

FIG. 30

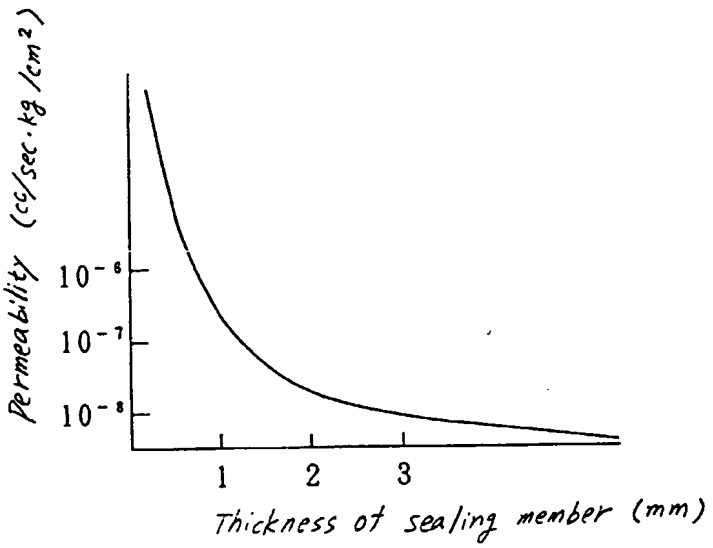
Permeability (cc/sec·kg/cm²)
10⁻⁶
10⁻⁷
10⁻⁸
1
2
3
Thickness of sealing member (mm)

FIG. 31

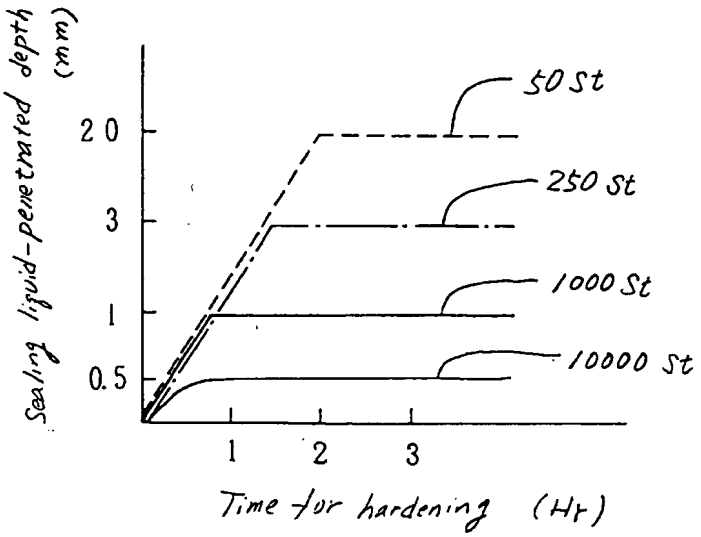
Sealing liquid-penetrated depth (mm)
20
3
1
0.5
50 St
250 St
1000 St
10000 St
1
2
3
Time for hardening (Hr)

FIG. 32